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Transparent dielectric elastomer actuator used as tunable optical grating

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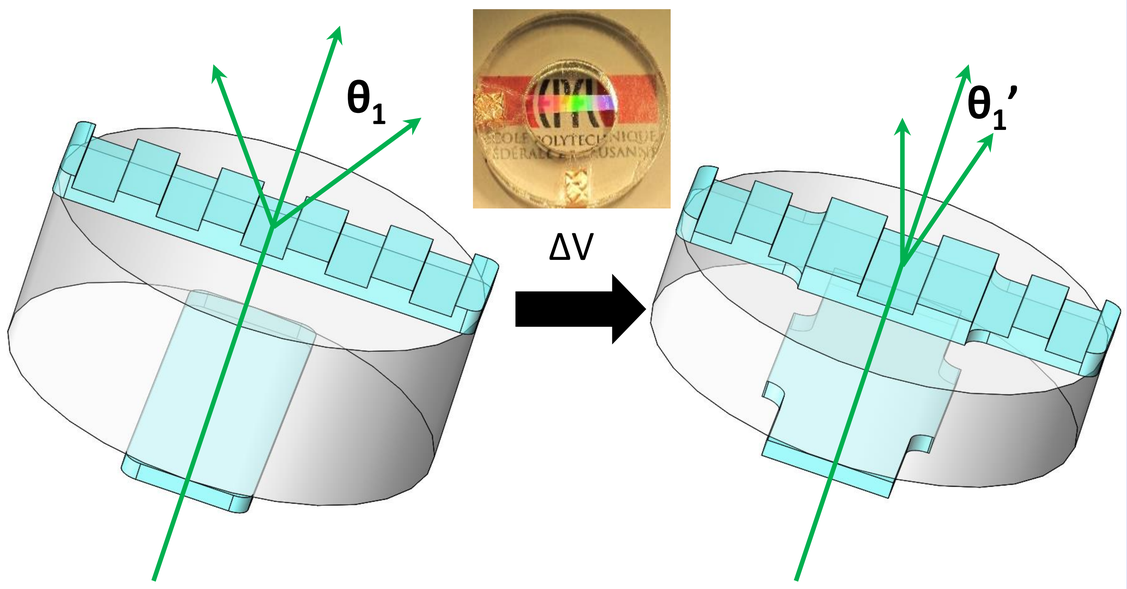
Abstract
Tunable optics has long been an active research topic, given the many advantages of dynamically changing optical properties[1]. Tunable gratings show a great potential for microscopy[2], projection displays[3], and telecommunication applications[4]. In this work, a transparent dielectric elastomer actuator is integrated into a tunable transmission grating. A 13 µm silicone membrane is sandwiched between two 750 nm transparent ionogel electrodes to fabricate a transparent dielectric elastomer actuator. By structuring the top transparent ionogel electrode into a sinusoid grating profile with a period of 2 µm period, the transparent dielectric elastomer actuator can be used as a tunable transmission grating. The structured stretchable electrode plays both the role of electrical conductor and optical grating. When 1.3 kV is applied between the two electrodes, the actuator presents a linear strain of 12.8 %, which correspond to a 1.4 degree change in the first diffraction angle for green light. The transparent ionogel electrode also presents a self-clearing property, thus further extending the lifetime of the actuator at high drive voltages. The ionogel electrodes maintain the accurate grating shape for several weeks, and could be structured into the shape of any diffractive element.

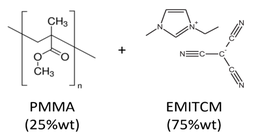
Tunable grating design concept



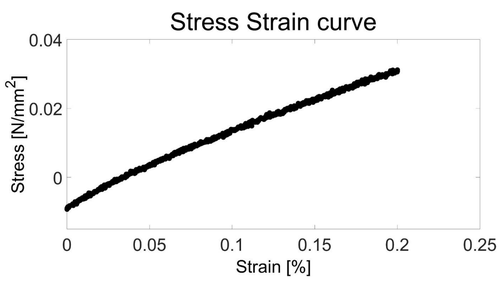
The transparent conductive grating is the top electrode of a Dielectric Elastomer Actuator (DEA). The second electrode, also made from a transparent ionogel, is oriented perpendicular to the top electrode, on the other side of the PDMS membrane. When the DEAs is actuated by applying a voltage between the two electrodes, the membrane expands in plane, increasing the grating period.

Ionogel properties

(1) Composition
Linear Poly(methyl methacrylate) (PMMA) + Ionic liquids: 1-Ethyi-3methylimidazolium tricyanomethanide (EMITCM)

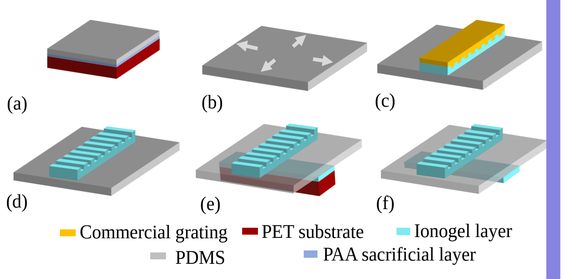


(2) Surface resistance
R□ = 770 kΩ/□ (For 750nm)

(3) Young's modulus


Y = 183 kPa

Tunable grating fabrication process



Conclusion and outlook
A transparent Ionogel has been structured into a precise grating and used as transparent DEA electrodes. The device shows good performance in both electrical and optical properties. The self-clearing property can extend the DEA lifetime. This approach opens new possibilities for making tunable optics, such as highly transparency tunable lenses [5].

Acknowledgments
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Reference
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[2] M. Aschwanden, D. Niederer, and A. Stemmer, Proc. of SPIE 2008 6927, 69271R-1.
[3] O. Solgaard, O. Solgaard, F. S. A. Sandejas, and D. M. Bloom Optics Letters 1992 17 688.
[4] A. Kocabas and A. Aydinli, Opt. Express 2006 14, 10228.
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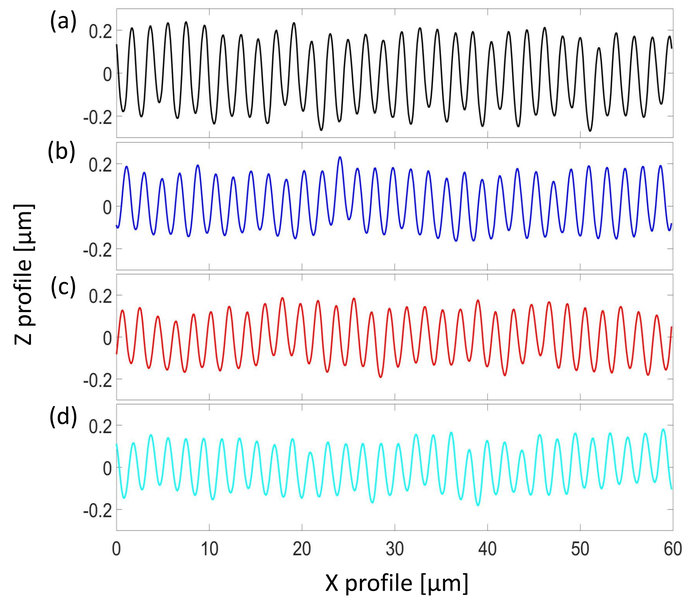
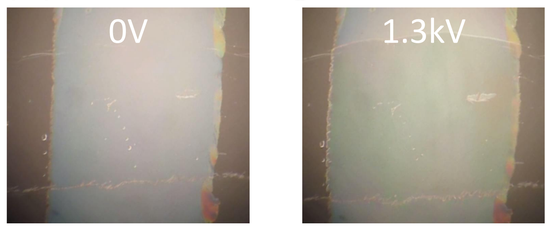
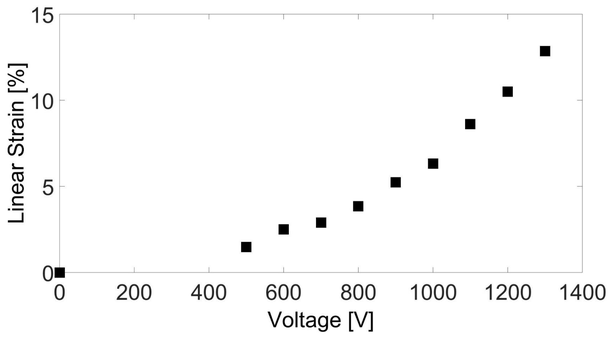
Tunable grating characterization

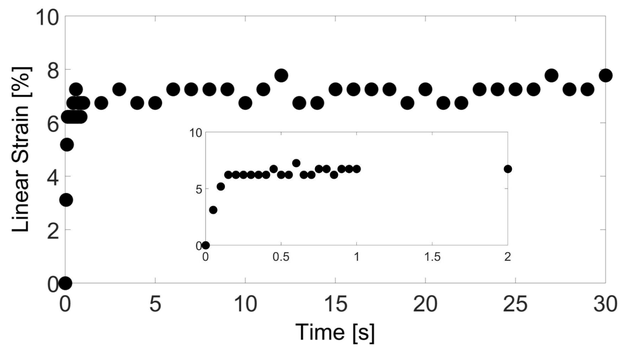
(1) Stability of Ionogel grating
Height profile of the grating shaped ionogel electrode.

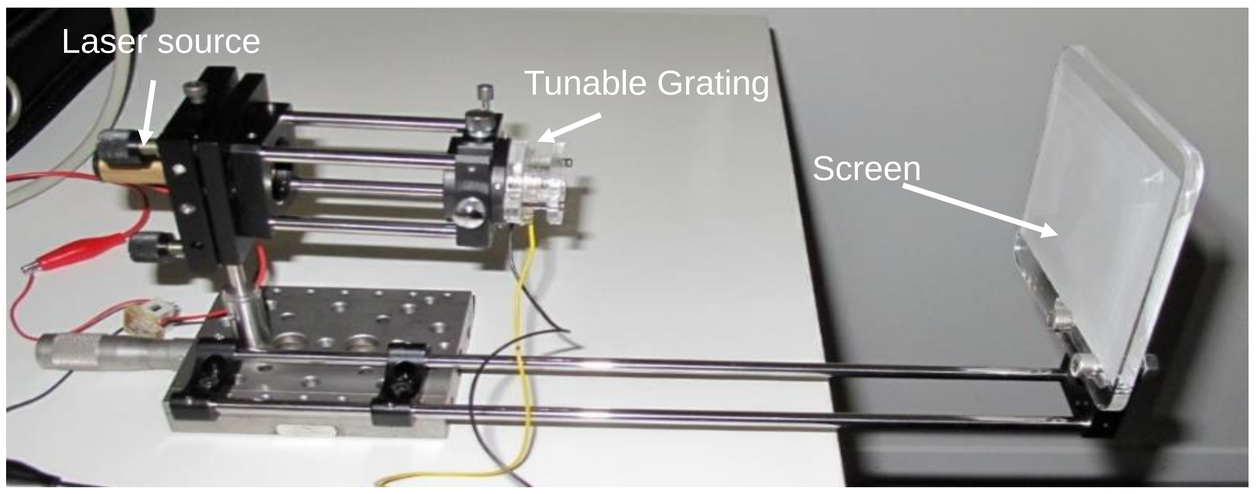
(a) As fabricated
(b) After 1 week of storage
(c) b + 500 actuation cycles
(d) c + 1 week of storage



(2) Strain Voltage curve




(3) Strain Time curve


(4) Optical Characterization setup


(5) Voltage control of the first diffraction angle